The Effects of Using Multiple Wavelengths in Optical Diffraction Tomography

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Abstract - Optical Diffraction Tomography (ODT) provides the ability to reconstruct 3D structure of optically transparent samples, for example, microbe colonies. In this work, we expand conventional ODT by using an ODT setup to illuminate the sample from different angles with multiple wavelengths, then apply the Multi-layer Born reconstruction algorithm to reconstruct 3D structure from the data obtained.

Introduction

- ODT measures the 2D optical field at various illumination angles using visible wavelengths. 3D refractive index maps of a sample are obtained from those images using the Multi-layer Born approximation[1].
- ODT enables visualization of the 3D structure of a sample without requiring fluorescence protein or organic/inorganic dyes [2].

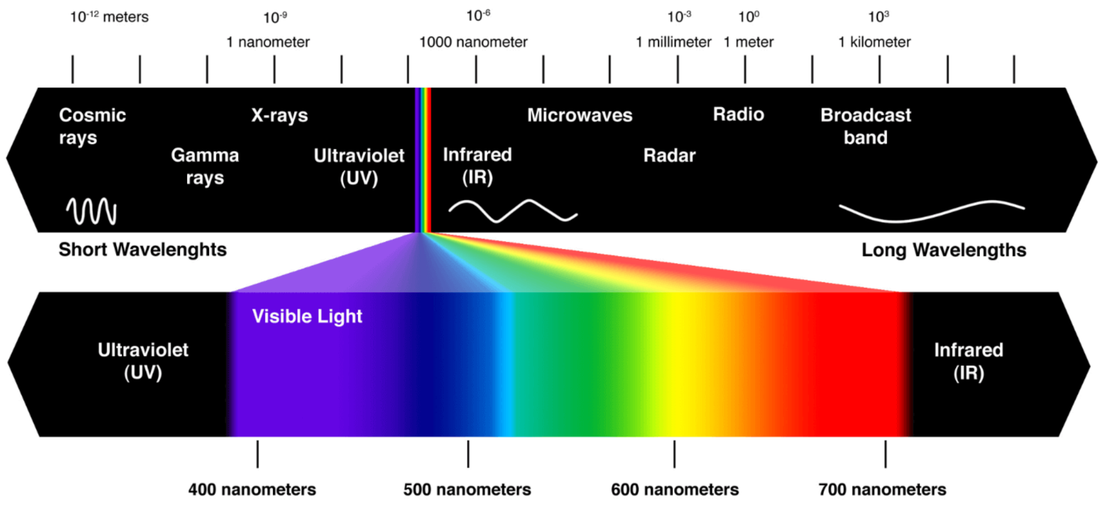

Fig 1. *Visible Wavelength Spectrum [3]*

Method

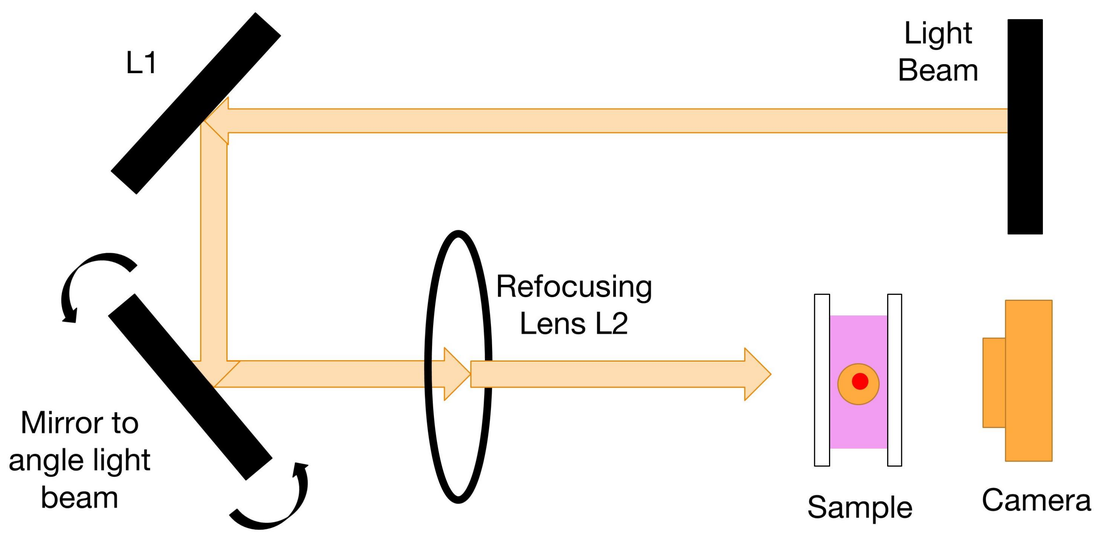

Fig 2. *Optical Setup for ODT*

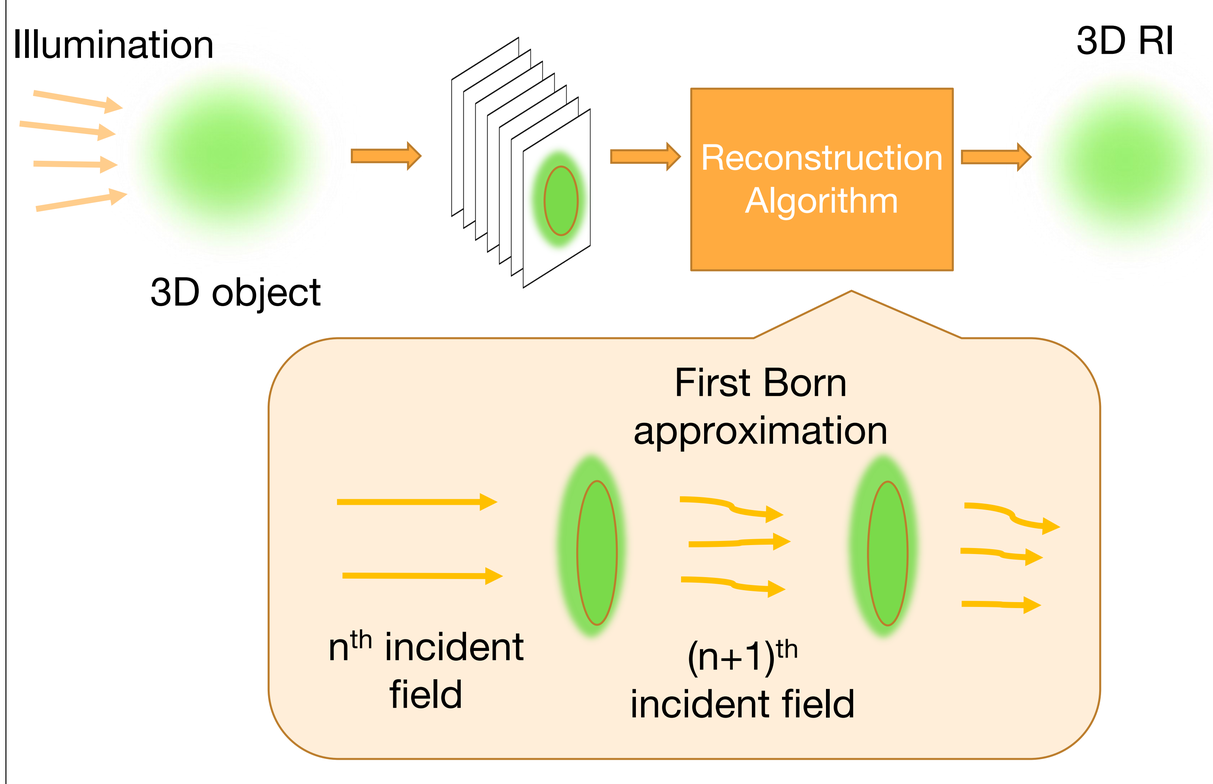

Fig 3. *3D Image Reconstruction Algorithm*

Results

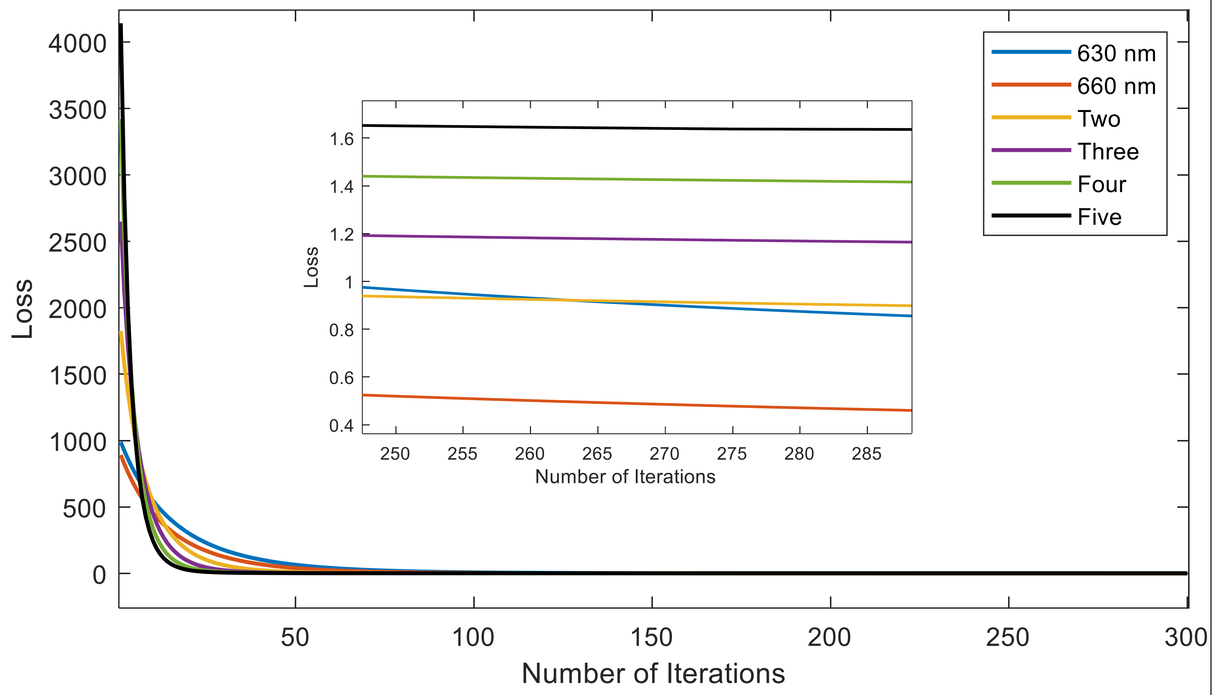

Fig 4. *Learning curve of using one single wavelength per simulation: 630 nm, 660 nm; and multiple wavelengths (from 2 to 5) between 630 nm and 660 nm*

Fig 5. *A layer of a 3D image reconstruction structure of a stack of circles on top of each other.*

Conclusion

- For single wavelength simulation, shorter wavelengths generate sharper details, meanwhile, longer wavelengths result in smoother 3D structures.
- Adding more wavelengths at different angles of illumination reconstructs sharper images, but for smoothing purposes, increases reconstruction error. Therefore, using multiple wavelengths allows sharper reconstruction, however, does not replace the use of higher diffraction angles.

References

[1] M. Chen, D. Ren, H.-Y. Liu, S. Chowdhury, and L. Waller, "Multi-layer Born multiple-scattering model for 3D phase microscopy," *Optica*, vol. 7, no. 5, pp. 394–403, May 2020, doi: 10.1364/OPTICA.383030.

[2] K. Kim, J. Yoon, S. Shin, S. Lee, S.-A. Yang, and Y. Park, "Optical diffraction tomography techniques for the study of cell pathophysiology," J. Biomed. Photonics Eng., pp. 020201-1-020201–16, 2016, doi: 10.18287/JBPE16.02.020201.

[3] Lee, Aaron, "Electromagnetic Spectrum", digital image, British Columbia/Yukon Open Authoring Platform, accessed August 3rd, 2022, <https://pressbooks.bccampus.ca/lightingforelectricians/chapter/the-em-spectrum/>

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